Practical Aspects of Virtual Reality Technology in Research and Educational Environments

Germans, D.M.

2008

Chapter 5

Conclusion

This chapter gives an overview of the research done in this thesis. It gives a summary of all conclusions made in the various chapters, and addresses the research questions proposed in the introduction.

5.1 Summary

Chapter 2: Tiled Displays

Chapter 2 shows how to realize a high-resolution stereo tiled display, using low-cost commodity hardware. It elaborates on a fully automatic calibration method that is used for geometric and photometric calibration. The display outputs a passive stereo image, using linear polarized light for stereo separation.

The calibration procedure works by displaying a checkerboard pattern on each projected tile. This pattern is photographed with a digital camera, and the photograph is analyzed with a subpixel-accurate matched filter analysis algorithm. The resulting checkerboard coordinates are fed into a model of the screen and the projectors, and using a non-linear least-squares fitting algorithm, image parameters for each projected tile are obtained. With these parameters, the projected tiles can be adjusted to form a seamless image.

Each tile has a localized 3D transformation that incorporates a correct stereo frustum calculation for a viewer standing at a distance in front of the screen. The inter-ocular distance is taken into account. The resulting stereo images are convincing.

Drawbacks of the method include color and intensity differences among different projectors, as well as non-Lambertian screen characteristics for which photometric calibration is only possible for a single point in the audience. Using automatic calibration, the user can comfortably show 3D stereo visualization and incorporate this in education and research activities.

Chapter 3: Software Infrastructure

Chapter 3 shows how to create a toolkit that, in a platform-independent way, integrates a wide variety of VR technology setups with scientific visualization and measuring paradigms that are used by lecturers and researchers. The proposed toolkit consists of 3 parts: Aura for the platform-independence, VIRPI for VR events and widgets and CAVEStudy for communication with existing datasets or running simulations and measurements. The toolkit has been demonstrated via a set of case studies.

Even though the case studies have not been performed explicitly by domain experts, Aura, VIRPI and CAVEStudy show great flexibility and utility in a wide range of applications in an educational or research-oriented setting. Aura can be used on setups like the IC-Wall tiled display, as well as in the CAVE, or on the Responsive Workbench. In several case studies, a prototype application that interfaces with existing unaltered software was created with very little effort.

Chapter 4: Case Studies

Chapter 4 elaborates on two large case studies that have been performed in the context of this thesis: root canal measurement in VR and interfacing with the RoboCup soccer simulation system in VR. Next to this, the chapter shows how Aura and the ICWall have been used to give lectures on various topics.

Measuring the length of the root canal of a tooth in VR is done by capturing the 3D structure of a tooth with local computed tomography. A tooth is exposed to a very narrow and low-dosage X-ray beam, at the end of which a CCD device captures an image. This is done at different angles to obtain a series of opacity images of the tooth. From this set of images, a 3D volume is computed and subsequently visualized in VR with Aura, VIRPI and CAVEStudy. Then, a flexible measuring yardstick is visualized inside the recreated 3D model of the tooth, and a user can position the yardstick inside one of the root canals. This way, the length of the root canal is measured. To get a correct measurement, the yardstick is calibrated by measuring a shape of known size in the same manner, prior to measuring the root canal.

For the RoboCup simulation system, an interface was created between a real human in the CAVE, and a simulated soccer game. The user in the CAVE can, via a special foot-tracker, interact with the virtual ball of the simulation and thereby interact with the simulated soccer player agents. The system was tested by having people perform specified soccer-related tasks, like walking around a box, dribbling with the ball, etc. Finally, a soccer match was played by connecting two VR processes from Amsterdam and Stockholm to the same soccer simulation. Work on this application ultimately led to the development of Aura, VIRPI and CAVEStudy.

The ICWall demonstrates the feasibility of a high-resolution display at low cost. Several dozens of enthusiastic users have used the ICWall for about 1000 hours in total for classes, as well as research projects. In general, the user experiences were very positive. The users appreciate both the large surface and the high resolution of the wall. The large surface is primarily used for education, to display multiple aspects of the subject being studied, or to explain correlations between different entities. The high resolution, on the other hand, is exploited mostly by researchers, who need it to display very large data sets.

5.2 Discussion

To conclude this chapter and thesis, we will revisit the research questions posed in Chapter 1.

How does one set up a fully automatic geometric and photometric calibration procedure for projector-based tiled displays, such that the result is accurate enough to produce convincing (stereo) images?

Chapter 2 explains the complete process of automatic geometric and photometric calibration. The accuracy can be clearly measured, as are the limitations of the solution: color and brightness differences among projected tiles, partially due to non-Lambertian screen behavior.

How does one develop a high-level VR toolkit running on different VR setups that can be used by domain experts?

This question has several aspects. Domain experts are supposed to be programmers that know C/C++, whereas course lecturers are usually not programmers at all. Also, in research environments there might be a program-savvy researcher, but this is by no means a given, so at least some kind of external assistance is required. This assistance does not have to be a full-fledged VR specialist, as shown in the case studies in Chapter 3, which were mostly done by students from outside computer science.

Next to this, creating an API that is suitable for rapid prototyping, and has the right features, is not trivial either. Aura succeeds in providing a platform-independent base for rapid prototyping, but it lacks certain features. This was a deliberate choice, because the API should be simple and easy to understand, but education and research projects that consider the use of Aura might need much more visualization functionality, as well as more interactive features.

What has been shown in the ICWall implementation of Aura is that a well-considered API allows performance optimizations to be done to a great extent. This in itself has been the onset of the Ph.D. research project of Tom van der Schaaf [89].

Given a local CT setup and given this toolkit, can one show that measuring of a molar root canal in 3D benefits from the added value of VR?

Given the volume data of the tooth and the calibration of the yardstick, the root canal can be measured with at least as much accuracy as is possible when physically measuring the root canal. This is more accurate than the traditional X-ray photo estimation method that is being used by dentists everywhere.

A dentist will likely not procure a complete CAVE-like VR setup, but the technology shows that with different analysis techniques and a different approach to measuring, better results for the patients can be obtained.

What is the added value of classroom VR for education?

The ICWall is a seamless big screen and has a high resolution. These are the two main benefits that lecturers find in using the technology. The screen has been used extensively to present multiple views and large datasets, but much less using 3D graphics or custom applications.